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Evaluation of the Peaking Factor Measurement Uncertainty for 3-String MAPSSEL Vanadium Detectors

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1. Introduction

A long-life fixed in-core detector assembly design, which named MAPSSEL(**M**onitoring **A**nd **P**rotection **S**ignal **S**eparation **E**xtended **L**ife), was developed as part of a joint program between Korea Electric Power Research Institute (KEPRI) and Westinghouse Electric Company (WEC). The final detector assembly design consists of six vanadium (Va) detectors used for core monitoring system and three platinum (Pt) detectors for core protection system, as shown in fig. 1.[1] In the previous evaluation of measurement uncertainty has been demonstrated that 6-string MAPSSEL Va detector design can safely replace the existing Rh detector design, as shown in fig. 1.[2]

The Pt strings in the MAPSSEL detector produce prompt responding signal and will be used for core protection in the CPCS in the future. The Pt signal will be calibrated to the Va measured power distributions periodically. At the calibration time, the power distribution and the Pt detector currents are stored as the 'reference'. At the following time steps, the 'measured' Pt detector currents will be compared with the 'reference' Pt currents. Then the 'reference' power distribution is corrected by the ratio of Pt currents.

Therefore, the uncertainties of the Pt detectors can be defined by the same methodology as the Va detector in the MAPSSEL detector, except that the Pt detector has only three strings. In this study, the simulated Pt current was generated as if is is a Va emitter.

The peaking factor measurement uncertainty of 3-string MAPSSEL Va detectors is evaluated by simulation methodology.

2. Methods and Results

A peaking factor measurement uncertainty of 3-string MAPSSEL Va detector was performed for the Yonggwang Nuclear Power Plant, where 45 detector strings with five detector elements are installed in a core of 177 fuel assemblies.[3] A simulation methodology was used to generate pairs of 'true' and 'predicted' power distributions analytically. A simulated measured current is obtained analytically from the 'true' power distribution. [2,4]

The measurement uncertainty is defined by the 95/95 upper tolerance limit from the percent deviations of detector-signal adjusted nodal powers from the 'true' nodal power over the highest power density locations.

Total uncertainty of 3-string MAPSSELVa detector is showed in Fig. 3(LHS). In considering the large axial offset differences between 'true' and 'predicted' excessive(ΔAO), uncertainty penalty is introduced as bellows;

$$U_{F_Q}(\sigma, F_D, \Delta AO) = U^B_{F_Q}(\sigma, F_D) + U^P_{F_Q}(\sigma, F_D, \Delta AO) \qquad (1)$$

Where: $U^B_{F_Q}(\sigma, F_D)$ is base term, RHS in Fig. 3

$U^P_{F_Q}(\sigma, F_D, \Delta AO)$ is penalty term ,table 1&2

F_D : Fraction of detector deletion

3. Conclusion

As a result of the evaluation for 3-string Va detector, it is observed that;

a. $F_{\Delta h}$ uncertainties are very similar with 6-string design
b.. Trend of the Fq uncertainties are similar for both designs. For high inoperable detector cases, the 3-string design shows lower uncertainties.
c. As long as the axial offset differences between 'true' and 'predicted', ΔAO, is not excessive, the 3-string design can provide similar peaking factor measurement uncertainties as the 6-string design.

The measurement uncertainty penalty of 3-string Va detector for excessive AO difference between 'true' and 'predicted' have been defined by bounding equation.

The next demonstration program planned, in the nea future, is using the MAPSSEL test detector assemblies in an operating reactor.

REFERENCES

[1] Design Spec. of MAPSSEL, WEC-KEPRI, 2006.
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[3] Y. S. Choi et, "Evaluation of the Platinum Detector Signal for YGN4 Cycle 5, " KNS Spring Meeting, May 2003.
[4] Y.S. Choi, T. Morita, M. Heibel., "Peaking Factor Uncertainty of MAPSSEL Detector for Six and Three String Systems, " WEC, June 2005.

ACKNOWLEDGEMENTS

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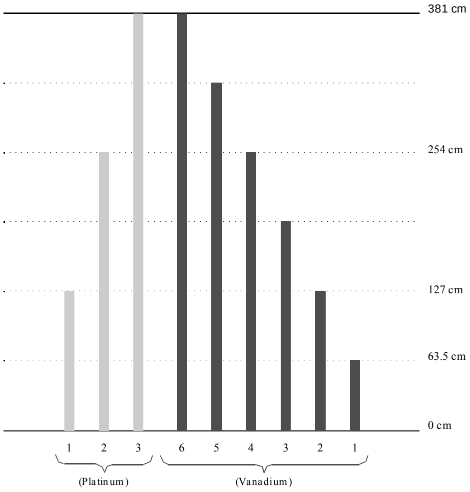

Figure 1 MAPSSEL Detector Assembly Detector Element Configuration

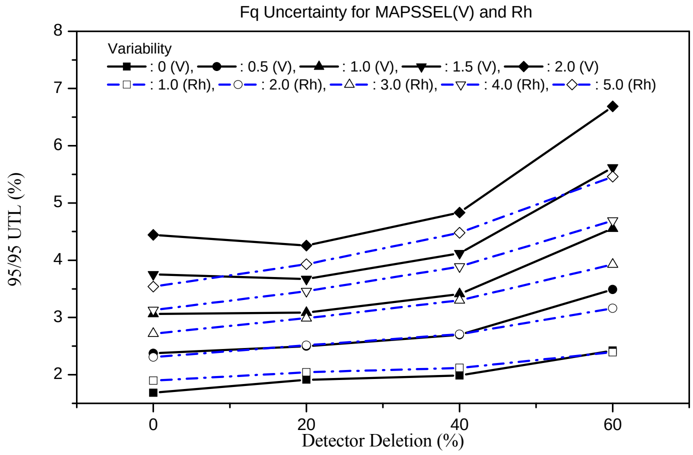

Figure 2. Peaking Factor Uncertainty vs. Fraction of Inoperable detectors for 5 element Rh and MAPSSEL 6 Va detectors

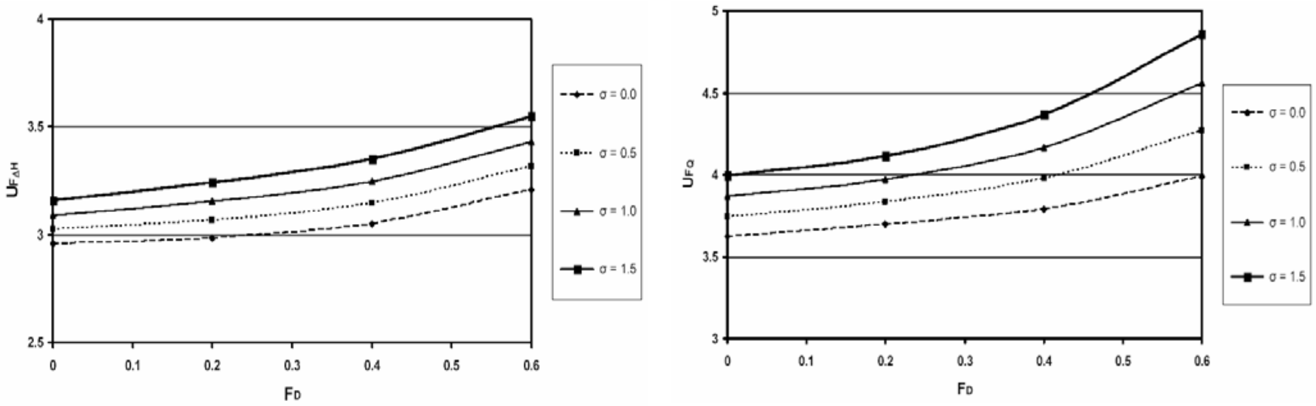

Figure 3. Total $F_{\Delta h}$ and F_q Uncertainties for ｜Δ AO｜＜10 % 3-string MAPSSEL Va Detectors

Table 1. Fq Uncertainty Pernalty for Large Δ AO (+AO)

Inoperable Detector Fraction 0.00					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
10.0	-0.182	-0.026	0.129	0.284	0.439
15.0	1.051	1.182	1.314	1.446	1.577
20.0	2.288	2.396	2.504	2.612	2.720
25.0	3.529	3.614	3.698	3.783	3.867
30.0	4.775	4.836	4.897	4.958	5.018
Inoperable Detector Fraction 0.20					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
10.0	-0.091	0.024	0.138	0.253	0.367
15.0	1.173	1.264	1.355	1.445	1.536
20.0	2.441	2.508	2.575	2.642	2.710
25.0	3.713	3.757	3.800	3.844	3.888
30.0	4.990	5.010	5.030	5.050	5.070
Inoperable Detector Fraction 0.40					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
10.0	0.000	0.074	0.148	0.222	0.295
15.0	1.295	1.345	1.395	1.445	1.495
20.0	2.593	2.620	2.646	2.673	2.699
25.0	3.896	3.899	3.902	3.905	3.908
30.0	5.204	5.183	5.163	5.142	5.121
Inoperable Detector Fraction 0.60					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
10.0	0.092	0.125	0.158	0.191	0.224
15.0	1.417	1.426	1.435	1.445	1.454
20.0	2.746	2.732	2.718	2.703	2.689
25.0	4.080	4.042	4.004	3.966	3.929
30.0	5.418	5.357	5.295	5.234	5.173

Table 2. Fq Uncertainty Pernalty for Large Δ AO (-AO)

Inoperable Detector Fraction 0.00					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
-10.0	0.015	-0.021	-0.057	-0.093	-0.129
-15.0	0.504	0.470	0.436	0.402	0.367
-20.0	0.923	0.890	0.858	0.826	0.794
-25.0	1.271	1.241	1.211	1.181	1.151
-30.0	1.550	1.522	1.494	1.466	1.438
Inoperable Detector Fraction 0.20					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
-10.0	0.004	-0.091	-0.186	-0.281	-0.376
-15.0	0.536	0.442	0.349	0.256	0.163
-20.0	0.997	0.906	0.815	0.724	0.633
-25.0	1.388	1.299	1.210	1.121	1.032
-30.0	1.710	1.623	1.536	1.449	1.362
Inoperable Detector Fraction 0.40					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
-10.0	-0.007	-0.161	-0.315	-0.469	-0.623
-15.0	0.567	0.415	0.263	0.111	-0.041
-20.0	1.071	0.921	0.772	0.622	0.472
-25.0	1.506	1.358	1.210	1.062	0.914
-30.0	1.870	1.724	1.578	1.432	1.286
Inoperable Detector Fraction 0.60					
ΔAO (%)	Detector Variability (%)				
	0.0	0.5	1.0	1.5	2.0
-10.0	-0.019	-0.231	-0.444	-0.657	-0.870
-15.0	0.599	0.388	0.177	-0.034	-0.245
-20.0	1.146	0.937	0.728	0.519	0.310
-25.0	1.623	1.416	1.209	1.002	0.796
-30.0	2.030	1.825	1.620	1.416	1.211